

The Institute of Lubrication NATIONAL LUBRICATING INSTITUTE

Tentative N.L.G.I. Classification of Semi-Fluid Greases

GRADE—Worked Consistency.

(Modified A.S.T.M. Penetration with 30 gram cone and stem assembly). SEE NOTE 1

F-1	375-405	F-3	305-335
F-2	340-370	F-4	270-300

NOTE 1—Method of test is identical with A.S.T.M. D-217-38T for Consistency of Non-Fluid Greases except for the following modifications:

- The total moving weight of the cone and plunger rod attachment shall be 30 grams instead of 150 grams. This weight is critical and appreciable deviation will cause errors in penetration measurements.
- The grease worker cup of 3" inside diameter or a sample cup of 3" I.D. must be used for all tests with the 30 gram cone. Use of sample cups of larger diameter will result in large errors in penetration measurement.

NOTE 2—The tentative N.L.G.I. Classification of Semi-Fluid Greases is based on Consistency only and is not intended to evaluate factors of apparent viscosity, type of soap, mineral oil constituent, or quality. Some types of Semi-Fluid lubricants are more nearly similar to viscous fluids than to plastic greases in which case consistency measurements may be misleading if other properties are not taken into consideration. Specifically, it is possible to formulate two semi-fluid greases of substantially identical penetration

by the 30 gram cone but of markedly different apparent viscosities. Such a condition is related to the viscosity of the mineral oil constituent and type of soap base used in formulation.

Accordingly, consistency measurement alone of semi-fluid greases will not serve to define their service performance properties and other factors such as mineral oil viscosity, type of soap, etc., must also be defined.

NOTE 3—Some types of semi-fluid greases become markedly softer after the 60 stroke working in the A.S.T.M. Grease worker. The degree of change in some instances may be equal to a change of one or two N.L.G.I. grades. While the worked penetration is specified for the N.L.G.I. Classification in order to assure better agreement and reproducibility in the handling and testing of grease samples, this requirement may be undesirable in some circumstances.

In instances where the unworked penetration is of greater importance than the worked consistency the proposed N.L.G.I. Semi-Fluid Grease Classification may be used with the suffix "unworked."

NOTE 4—As a temporary service, plastic cones with aluminum tips and shanks weighing approximately 14 grams can be secured on order placed with G. W. Miller, Secretary, N.L.G.I., 498 Winspear Ave., Buffalo, N. Y. These 14 gram cones can be fitted to aluminum plunger rods of dimensions as required by the various makes of Penetrometer instruments and be adjusted to a total weight of 30 grams.



Technical Sub-Committee Report on the Tentative N.L.G.I. Classification of Semi-Fluid Greases

CARL GEORGI—Chairman Technical Sub-Committee

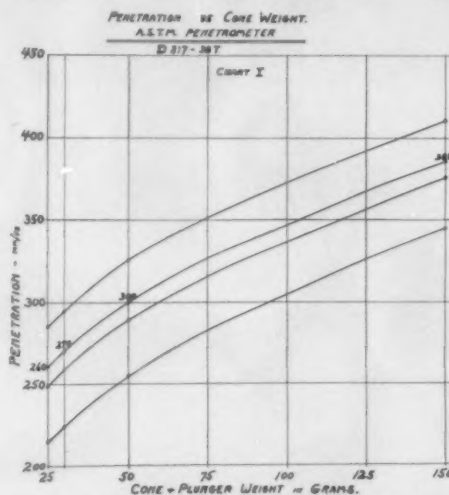
Following the request of the Army Supply Services, that the N.L.G.I. give consideration to expanding the Grease Consistency Classification to cover semi-fluid type greases, the Institute's Technical Sub-Committee on Test Methods and Classification conducted a survey of a number of grease laboratories to secure an idea of the general practice being followed by individual grease manufacturers in grading semi-fluid greases, as well as test methods used to measure semi-fluid consistencies.

A few grease manufacturers reported using either the S.I.L. Mobilometer or the Gardiner Mobilometer for consistency measurement of semi-fluid type products. While this type of test instrument possesses certain advantages in measuring the mobility characteristics of semi-fluid lubricants, the Technical Sub-Committee believed that one major disadvantage was involved, namely, the matter of apparatus availability. If a mobilometer type of instrument were recommended for general use in testing semi-fluid greases, a large number of laboratories would have to secure such instruments, since they are apparently in very limited application at the present time. With the current difficulties in securing special apparatus from supply houses, it would appear that a period of months might readily be required to get suitable mobilometers in general distribution throughout the industry.

The Sub-Committee's survey did indicate, however, that at least a dozen grease laboratories have been using modifications of the A.S.T.M. Penetrometer for the evaluation of semi-fluid grease consistencies, these modifications consisting of light weight Cones constructed either of aluminum or plastic of the same dimensions as the A.S.T.M. Brass Cone but having weights ranging from thirty to fifty grams instead of one hundred fifty grams. Since every grease laboratory has an A.S.T.M. Penetrometer, and since light weight Cones are relatively easy to secure, it was believed this type of test method would be the simplest and most easily adaptable under existing conditions.

As a first step in studying the effect of Cone weight on penetration, four samples of soft calcium base greases were prepared. These four samples were all sufficiently stiff to be measured with the standard A.S.T.M. Penetrometer with 150 gram Cone weight, and were also measured with Cones of 50, 30 and 25 grams weight respectively. Chart I shows the relation of Cone weight to penetration. It will be noted that for calcium base greases the Cone weight-penetra-

tion relationship is quite uniform. The one grease sample having a penetration of 385 with the 150 gram A.S.T.M. Cone, represents the softest N.L.G.I. No. 0 consistency.



This same grease had a penetration of 300 with the 50 gram Cone; 270 with the 30 gram Cone; and 260 with the 25 gram Cone. Accordingly, the approximate dividing line between non-fluid and semi-fluid greases may be set at these penetration values for the various weights of Cones.

In order to secure as much information as possible in the limited time available, forty samples of semi-fluid type greases were secured from nine manufacturers. These

forty samples represented a general cross section of semi-fluid greases, as manufactured and used at the present time, as to varying degrees of consistency, mineral oil constituent and type of soap base. These samples were accordingly used as the basis for evaluating light Cone test methods and for deriving a classification.

The forty samples of commercial semi-fluid greases were tested for penetration with Cones of the four different weights. Chart II shows the results of these tests. A large majority of the grease samples were too soft to secure test readings with the 150 gram A.S.T.M. Cone. Six of the samples were too soft to secure penetration readings with the 50 gram Cone, indicating that a Cone of this weight is still too heavy to cover the complete range of commercial semi-fluid lubricants. The 30 gram and 25 gram Cones provided penetration readings on all forty samples, and it appeared, therefore, that Cone weights in this order were most desirable.

A possible problem involved with the use of light weight Cones is that of buoyancy of floating errors. Chart III shows the volume displacement in cubic centimeters of the Cone of standard A.S.T.M. dimensions. The volume displaced by the complete Cone, equivalent to a penetration of 432, is 36.1 c.c.s. At a penetration of 400 the volume displaced is 26.5 c.c.s. In the range around

(Continued on Page 3)

CHART II
PENETRATIONS
COMMERCIAL SEMI-FLUID GREASES
(40 Samples from 9 Manufacturers)

Penetration Range	150 gm. cone	50 gm. cone	30 gm. cone	25 gm. cone
Under 275	0	0	7**	7**
275 to 300	0	5**	4	6
300 to 325	0	2**	7	10
325 to 350	0	8	14	11
350 to 375	7	12	4	4
375 to 400	2	7	4	2
400 to 440*	6*	1*	0	0
Too Fluid	25	5	0	0

*Many penetrometers will not measure depths exceeding 400.

**These greases are sufficiently stiff to come in N.L.G.I. No. 0 class.

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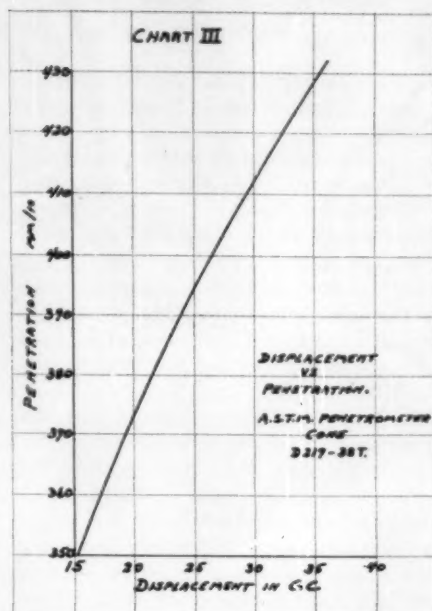
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400 penetration, therefore, the 25 gram Cone is close to the borderline where the weight of grease displaced, might equal or exceed the Cone weight with some types of greases, thereby involving floating or buoyancy errors. However, since most penetrometer instruments will not measure penetration depths exceeding about 400, the 30 gram Cone should have sufficient weight to avoid floating errors. As a summary, the 50 gram Cone was found to be too heavy to measure many types of commercial semi-fluid greases whereas the 25 gram Cone may possibly be too light and involve floating errors. It was believed, therefore, that the 30 gram Cone offered the best testing weight. "Cone weights" as mentioned herein refer to the total moving weight of the cone and plunger rod.

On the basis of the data accumulated the Proposed N.L.G.I. Classification of Semi-Fluid Greases, as appended, was adopted by the Institute Board of Directors as tentative.

Of the forty samples tested by the Sub-Committee, seven were of heavier consistency than covered by the proposed N.L.G.I. Semi-Fluid Classification, and were really

No. 0 N.L.G.I. Consistency products. Four of the forty samples came in the new F-4 class, fifteen in the F-3 class, nine in the F-2 class and five in the F-1 class.



Due to the limited time available, it was not possible to conduct an extensive program of cross checking penetrations with the 30 gram Cone in different laboratories, to secure data on test reproducibility. However, check tests by three laboratories on eight grease samples were secured and in all cases the agreement between laboratories was well within the limits of error prescribed by the present A.S.T.M. Method D 217-38T. Since a great many laboratories have been using light weight Cones for some time past, it would appear that the general idea of the test method is sound, and with proper attention to test procedure satisfactory test reproducibility can be secured.

It should be emphasized that the A.S.T.M. Penetrometer, either with the 150 gram Cone or the proposed 30 gram Cone, measures the consistency properties of greases but does not serve to evaluate other highly important physical properties such as apparent viscosity or mobility. If these various properties are defined briefly as follows:

Consistency — measure of the relative resistance of a plastic material to permanent change of shape.

Viscosity — measure of the relative resistance to flow.

Mobility — measure of the relative resistance of a plastic material to continuous deformation or flow after the yield value has been exceeded.

It is apparent that Cone penetration measurements alone do not evaluate many properties of greases which relate to service performance requirements, such as flow or mo-

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bility characteristics. Accordingly, consistency measurements by the Penetrometer are essentially of use only as a simple means

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Conical Cup for A.S.T.M. Penetration Test

PART I

By C. L. KNOPP

(Continued from June Issue)

The most desirable part of a worked sample of grease is at the center of the A.S.T.M. worker cup; while the top $\frac{1}{2}$ " layer, or portion chiefly involved in the ordinary cone test, is the most undesirable part of the whole sample. The top layer is invariably aerated unless special means are provided to eliminate aeration, such as our stuffing-box-riser method described later. Inasmuch as the perforated plate goes only up to, but not through the grease of the top and bottom layers, these portions may be considerably heavier than the mid-portion because of less working.

Reamer (o) is used to transfer the top $\frac{1}{2}$ " layer to the bottom of the conical cup; reamer (s) is used to transfer the mid-portion to the middle of the test cup; and (s') removes the remaining grease which may be distributed around the edge of the conical cup, if needed. The cup is grasped by the heavy handles and bumped until all air pockets are removed from the sample. The top is now struck off level and the cover (without thermometer) put on the cup so

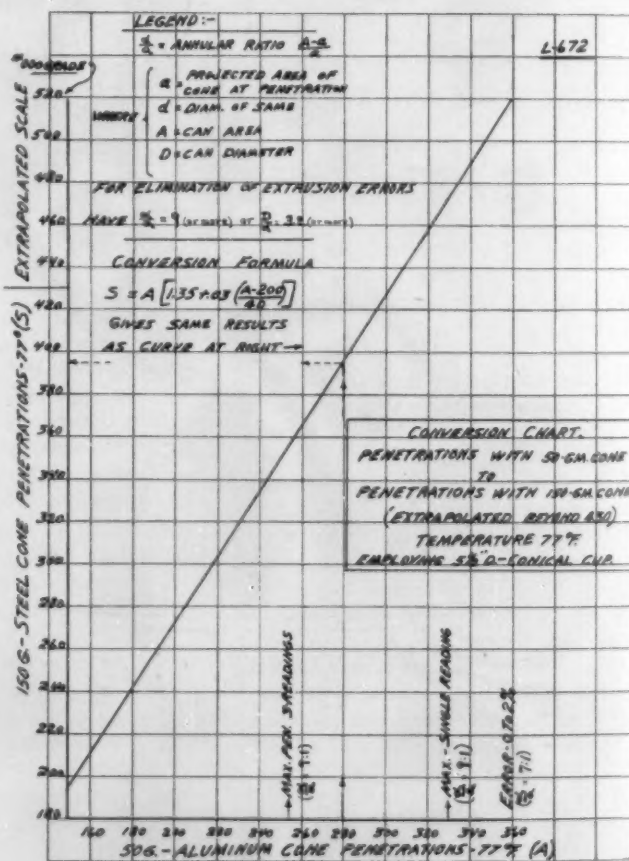
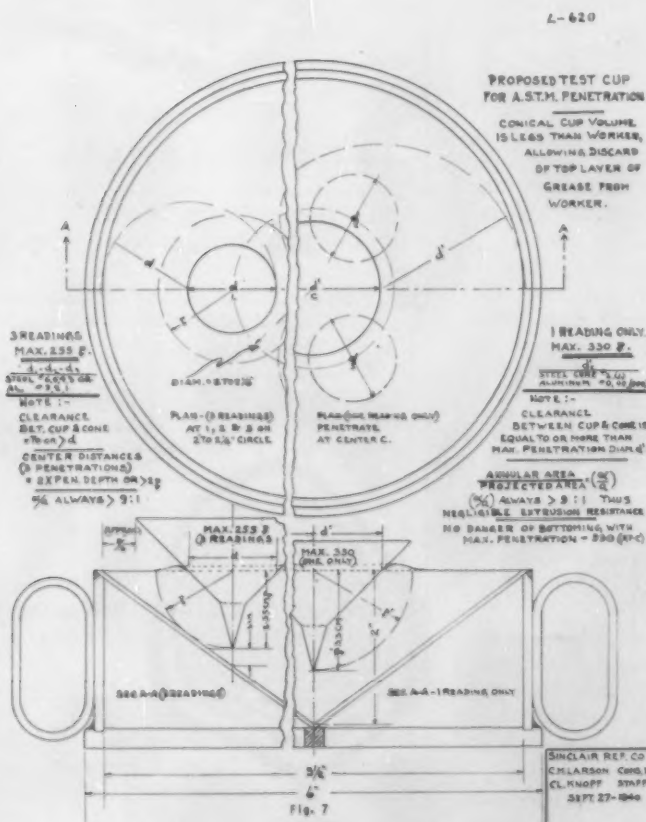
as to keep draughts and dust off the sample. Note $\frac{1}{4}$ " dead-air space. Immediately after the penetration is completed the cover is put on, and a Saybolt thermometer, (already reading about 77°F.), placed in the sample with bulb completely immersed. Temperature readings are recorded after one or two minutes, and if deviations are 2°F. or more, penetrations should be corrected. (A 2° difference in cup grease approximates 1.5 actual percent or 1 Pen. unit, and for an adhesive soda grease the correction may be 5.5% or 3 units.)

Referring to Fig. 7, it can be seen that three readings may be taken if the penetration is less than 255. If more than 255, only one reading should be taken at the middle of the cup. If this rule is observed, no extrusion errors will occur up to 330 penetration and only slight errors between 330 and 360. A close study of the drawings and notes (Fig. 7) will eliminate much discussion here; however, important points should be given special attention. The A.S.T.M. procedure recommends a penetration

depth as the minimum distance from tip to container wall. The sketches show that this should be about 2 penetration depths (P'). A better rule to follow is that discussed above:—namely, "do not exceed $(\frac{5}{8}) = 9$ " or "Penetration diameter should be less than $\frac{1}{2}$ the diameter of the Cup." Contrast this with an A.S.T.M. penetration of 400 in a 3" cup, in which the penetration diameter is 2.3", clearance only $\frac{1}{16}$ " and $(\frac{5}{8})$ only 0.7.

Fig. 5 shows that only grades 5 and 4 can be measured without extrusion errors, in a 3" cup with the steel cone.

With the conical cup and steel cone, grades 5, 4, 3 and 2 can be measured without extrusion, and when the aluminum cone is used grades 3, 2, 1, 0 and 00 may be measured without extrusion, while for 000 grade the error is slight. Grade 3 may be tested with either cone, but grade 2 and all lighter products should be tested only with the aluminum cone. For details, see the instructions on Fig. 9 and note arrow No. 1. Particularly note how aluminum-



cone readings are converted to the standard steel-cone scale. Also note how all cone readings can be converted to actual consistencies expressed in grams on the P.D. scale at left. It can be seen how the worked consistency of a grease may be expressed in percentage of the original unworked consistency; or comparison of two different greases may be expressed as a ratio.

The (S) and (A) lines of Fig. 9 are straight lines which are the loci of points representing calcium greases. Adhesive greases will fall to the left of these lines an amount depending on the adhesiveness of the grease. The consadometer P.D. test eliminates both adhesive and extrusion errors. Note the formula by which steel-cone readings (S) may be calculated from the aluminum-cone reading (A). It can be seen that the factor -f- is 1.32, 1.35, 1.38, 1.41, 1.44, 1.47 for Pen. 160, 200, 240,

280, 320, 360. The most convenient method of converting light-cone readings (A) to the standard penetration scale is by means of the curve given on Fig. 8. Note that the scale is extrapolated 90 units beyond 430, the actual height of the cone.

Conclusions:

The present A.S.T.M. method, using the steel cone and 3" cup gives results that are in error for products lighter than No. 4. The conical cup with the 150 and 50 gram cones measures without extrusion errors, all grades from 5 down to 00, and 000 with very slight error. Hence the number of grades and the range of consistencies have been increased fourfold, by the employment of the conical-cup method. A mixer cup, provided with stuffing boxes on the plunger rods and a riser tube, eliminates aeration. Middle samples from the worker cup are tested in the conical cup instead of the

usual frothy top layer. Better temperature control is also possible.

Fig. 8 makes possible a quick conversion of aluminum-cone readings to standard, steel-cone readings. Fig. 9 also may be used, but its most valuable use is in converting cone readings to P.D. grams, thus enabling one to express in true percentage the relative consistencies of two or more samples. Actual percent errors are approximately four times the errors of cone readings when the latter are expressed numerically.

The conical cup eliminates extrusion errors for all types of greases, but cannot correct the adhesiveness error caused by the shear resistance of adhesive products against the sides of the cone. The P.D. test eliminates both errors. With uniform products P.D. readings usually check within $\frac{1}{4}$ to $\frac{1}{2}\%$.

(To be Continued)

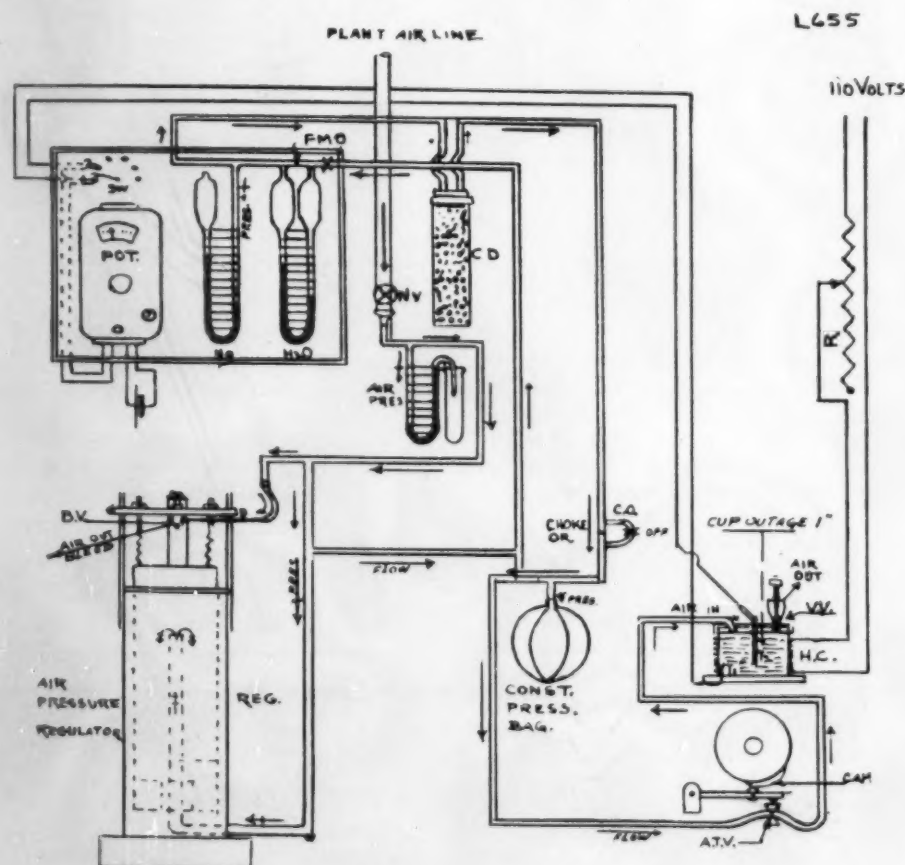


Fig. 9

MOTORIZED WORKER
0 TO 10,000 STROKES - 70° TO 400°F
WITH OR WITHOUT AERATION.

LEGEND:-

NV = NEEDLE VALVE
B.V. = BLEEDER VALVE
REG = PRESSURE REGULATOR
FMO = FLOW METER ORIFICE (#50 DRILL)
H ₂ O = FLOW METER MANOMETER
Hg = PRESSURE MANOMETER
C.D. = CAL. CL. DRYER
C.O. = CHOKE ORIFICE (#50 DRILL)
BAG = CONSTANT PRESSURE BAG
A.T.V. = AIR TIMING VALVE
AIR IN - AT ONE SIDE OF CUP COVER
V.V. = VENT VALVE (AIR OUT)
T ₁ = THERMOCOUPLE IN CUP WALL
T ₂ = THERMOCOUPLE MID OF SAMPLE
SW = SWITCH
POT. = POTENTIOMETER
H.C. = HEATING COIL (TO 400°F)
R = SLIDE-WIRE RHEOSTAT
AIR TIMING VALVE OPENS AT 1/4 DOWN-STROKE AND CLOSSES AT 3/8 DOWN-STROKE.
VENT VALVE (V.V.) IS OPEN ON DOWN-STROKE BUT CLOSED ON UP-STROKE.

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(Continued from Page 3)

of controlling product uniformity.

As pointed out in Note 2 of the Proposed N.L.G.I. Semi-Fluid Grease Classification, it is possible to prepare two greases of substantially identical Cone penetration which will be quite different as to apparent viscosity or mobility. Such differences are related to the viscosity of the mineral oil constituent and the type of soap base used. Accordingly, consistency measurements by Cone penetration will not serve to define service performance properties of greases and other factors such as mineral oil viscosity and type of soap must also be defined.

A major shortcoming of the lubricating grease industry at the present time lies in the fact that practically all grease properties are now measured with apparatus giving purely arbitrary readings which have little or no direct relation to actual service requirements. Until grease testing apparatus are developed which will measure grease properties in fundamental units capable of being translated into terms of service performance, test methods having obvious shortcomings, but supplying an immediate need, must be used.

A most important phase of this problem is the development of a pressure viscosimeter which will measure the viscosity—shear rate properties of greases in fundamental

units, to replace the various types of penetrometers, mobilometers and fixed shear viscosimeters which have been proposed in the past. This problem is well recognized by many grease technologists and active work is now under way to develop such an instrument. Many grease manufacturers therefore believe that grease consistency classifications based on penetration measurements in arbitrary units are a temporary expedient to take care of an immediate need and that the near future will bring the development of greatly improved test methods and subsequent classification of greases on a sounder technical basis.

PENETRATION VS. TEST CUP SIZE

The suggestion was made by two laboratories that test cups of larger diameter than the 3" A.S.T.M. Worker Cup might be used to avoid so called "extrusion errors." Test cups of 6" diameter and the Knopf Conical Cup of approximately 6" diameter were specifically mentioned.

Chart IV shows data on penetration readings with test cups of different diameters. Included are penetration data on typical non-fluid greases with the standard 150 gram A.S.T.M. Cone and data on several semi-fluid greases with the proposed 30 gram Cone.

Apparently with greases having penetrations in the order of 200 or less, test cup size does not have appreciable effect on penetration readings. With softer greases, test

cup diameter is a significant factor, and use of a 6" diameter cup, instead of the 3" A.S.T.M. Cup, increases penetration readings from 20 to 50 or more units depending upon the type of grease. This order of change applies both to non-fluid greases tested with the 150 gram Cone and to semi-fluid greases tested with the 30 gram Cone. Tests in the Knopf Conical Cup gave penetration readings substantially similar to those obtained with a 6" diameter cylindrical cup.

Since the penetrometer apparatus gives readings in purely arbitrary units, so called "extrusion errors" with the 3" Cup are purely arbitrary errors. As long as reproducible results are secured by the penetrometer with the 3" Cup, now in general use, it is questionable if extrusion and "arbitrary errors" are of any great practical significance.

If a larger test cup were specified at this time, it would be necessary to revise the N.L.G.I. Consistency Classification for the No. 3, 2, 1 and 0 grades. Since both the A.S.T.M. Penetration Method with 3" Cup and the N.L.G.I. Consistency Classification are in general use throughout the industry, it was not considered advisable to propose quite drastic changes either in test method or classification at this time, particularly in view of the fact any such changes would have little practical significance and would be likely to cause considerable confusion with respect to existing grease specifications.

CHART IV.
PENETRATION VS. TEST CUP DIAMETER

Type of Grease	3" Cup 150 gm. Cone	4" Cup 150 gm. Cone	6" Cup 150 gm. Cone
Lime Base	203	203	205
Soda Base	232	233	240
Lime Base	336	355	372
Al Base	330	344	353
Soda Base	340	355	370

Type of Grease	3" Cup 30 gm. Cone	6" Cup 30 gm. Cone
Lime Base	224	223
Lime Base	259	263
Lime Base	294	313
Lime Base	325	360
Lime Base	345	390
Soda Base	274	276
Soda Base	365	400



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This LIQUI-SWAT display, illustrated above, measures twelve inches from top to base. An ingenious die-cut loop fits snugly around the cap of the full-size LIQUI-SWAT can which rests in turn on the base of the display. This arrangement holds the display rigid, and makes it very easy to assemble.

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Gasoline Dealers Pick Up Business Through Laundry Pick-Up

How the changing times affect gasoline dealer operation is effectively illustrated by the following account of a new idea recently reported to us.

A laundry company in a small city realized that they would be unable to maintain their complete house-to-house pick-up and delivery service in the face of a ban on tire sales, except by rationing certificate. They figured out that if they had three or four well-located pick-up and delivery points, their daily mileage would be cut considerably and they could correspondingly spread their operation over a longer period of time.

With this thought in mind they picked certain gasoline service stations which were centrally located in respect to the areas in which the city was divided, and then made a deal with these stations whereby they would act as delivery and pick-up points.

They had a strong point to make with the station operator in a deal of this kind, because it meant that the operator would benefit in the following way:

1. The laundry truck or trucks involved would spend a considerable amount of time in each station during the pick-up and delivery periods and the operator would have the opportunity to completely service the trucks with gasoline, oil, lubrication and all other services.
2. Many laundry customers would bring their bundles to the pick-up station in their cars and would also call back for the finished bundles in their cars. This would create additional traffic and potential customers for the stations acting as delivery points.

No provision was made for a commission to the operator on the laundry bill because the laundry operator would continue to handle all credit and collections as he had previously under the old house-to-house setup.

According to latest reports this new idea seems to be working out very well for all parties interested and a real conservation effort is being accomplished. The laundry company is saving on gasoline, oil, tires, and wear and tear, and at the same time makes its vehicles available for daytime service work during their stay at the distribution points.

The station operator has had additional traffic created for him and, by tying in with the conservation angle used by the laundry

company, has an excellent selling point to use on the laundry customers who drive into his station.

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